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DFM & SIMULATION FOR INJECTION MOULD OF KNOB

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ABSTRACT

This work deals with injection moulding simulation of Knob, in which the gate location, diameter and the possible defects during the filling& packing phase is determined and warpage effects under variable shrinkage with process parameters. In this simulation process is carried out by using Hyper mesh and Mould Flow Software. In the Hyper mesh phase, meshing works are carried along with thickness assignment. In the Mould Flow phase, material flow, positioning of gate location, gate size and analysis of defects are determined here. The component tested virtually is Knob that used to set/tune the time for a wash in Washing machine.

KEYWORDS: Injection Moulding Simulation, Hyper Mesh, Mould Flow Software & Warpage Effects

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Original Article

INTRODUCTION

The injection molding has seen steady growth since its beginnings in the late 1800s. The technique has evolved from the production of simple things like combs and buttons to major consumer, industrial, medical, and aerospace products.

INJECTION MOULD SIMULATION

Part Review: (DFMA)

The basic principle of part review is to ensure the better final results of the part.

We must have the data about the part which is mentioned below

Part Details

- Shrinkage
- Material
- No of cavities
- Inlet type(gate)
- Surface demands
- Engraving is required or not

These are the things; we have to know before we start the review

Draft

The draft is based on material type (ABS/PP/PE/PC) and surface demands.

Surface Demands

No visible surface, blasted surface (fine, medium, coarse)/grain 320.

Matching Draft

- The vertical wall matching should have Proper draft.
- The part should be 7° matching draft for improving tool life.

Parting Surface

- If the part has side hole, it requires slider (side core)then we need to check where slider parting line will come.
- Giving information to the customer before the tool design about the Parting line and get approval if required

Sink Marks

- Is depression on the surface, mainly due to improper rib thickness ratio. It is formed opposite to the rib.
- Review the Part for sink mark in terms of wall thickness, rib width
- The ratio of the rib should be 0.5 to 0.7t.

Gate Point

During the part review, we need to specify the best inlet point

Equal Wall Thickness, Warpage

If the part has varying wall thickness, it causes war page on thin sections

Sink Mark at Screw Stiffners

If the screw stiffner is formed on angular surface, it causes sink mark on the visible surface.

Cores

If the part has deeper holes, it's difficult to dissipate the heat in the core side. The following suggestions have to be done.

- If the length of the hole is greater than (diameter of hole X 7). Then we go for proposal A.
- A-split the hole form both sides
- B-make the bigger diameter

Engravings

Reviewing the part for engravings should be machinable. Letterings should have,

- min 0.4mm wide&
- Max 0.25 high.

- Deep 0.2 mm.
- Distance between two engravings is 0.4mm.

Undercut causes the obstruction in the part (not come out from the cavity while opening the mould).

There are 3 types of Draft –

- if any feature in the part is more than90 deg is called as a positive draft(preferable)
- If it is equal to 90 deg is call it as a No draft(neutral draft)
- It is less than 90 deg is call it as a Negative draft(undercut)

DESIGN FOR MANUFACTURING

In this, the given CAD geometry is checked whether it is designed as per the DFM guidelines, such as

- Sharp edges & Fillet radius
- Sink mark
- Uniform part thickness
- Draft angles
- L/D ratio& Thin steel condition in core

Table 1: Part Envelope Value

Part Name	Part No.	Part CAD Volume (cm^3)	Part Envelop (X mm*Y mm*Z mm)
KNOB	W10XXXXXX_A10	11.5	Ø50.3/30
	W10XXXXXX_A11	10.6	Ø48.5/30

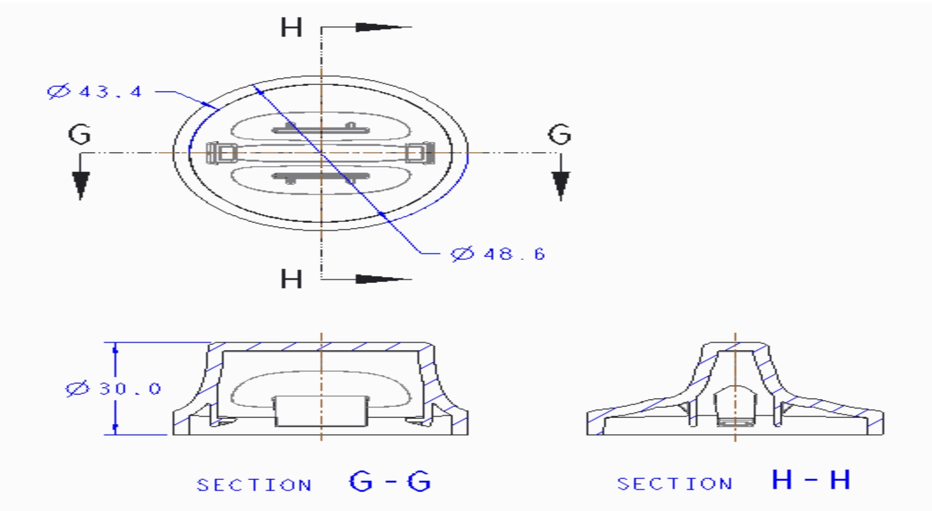


Figure 1: Knob with Dimension.

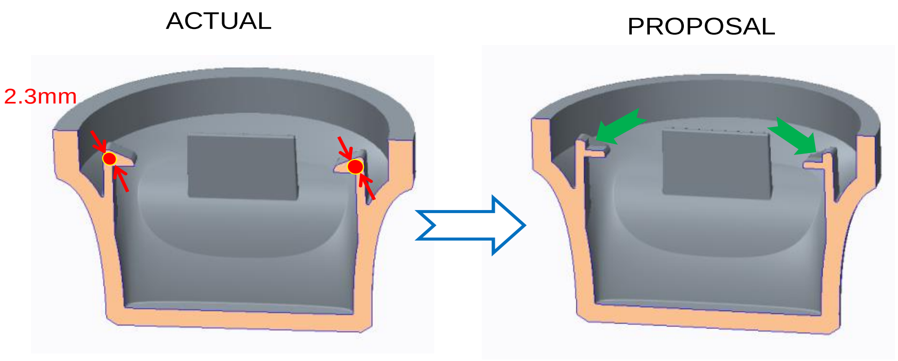


Figure 2: Recommendation 01: Core Out Chunky Regions.

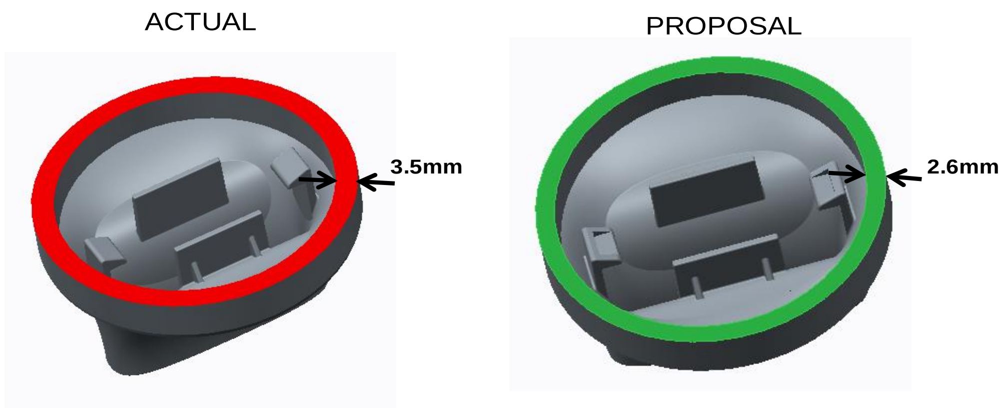


Figure 3: Recommendation 02: Keep Uniform Wall Thickness.

Meshing

- Defeaturing the corner radius.
- Generating midplane
- Generating & repairing mesh
- Checking the element quality, free edges, connectivity issues, aspect ratio, duplicate elements & Jacobian.
- Thickness assignment by measuring the thickness of the CAD geometry.

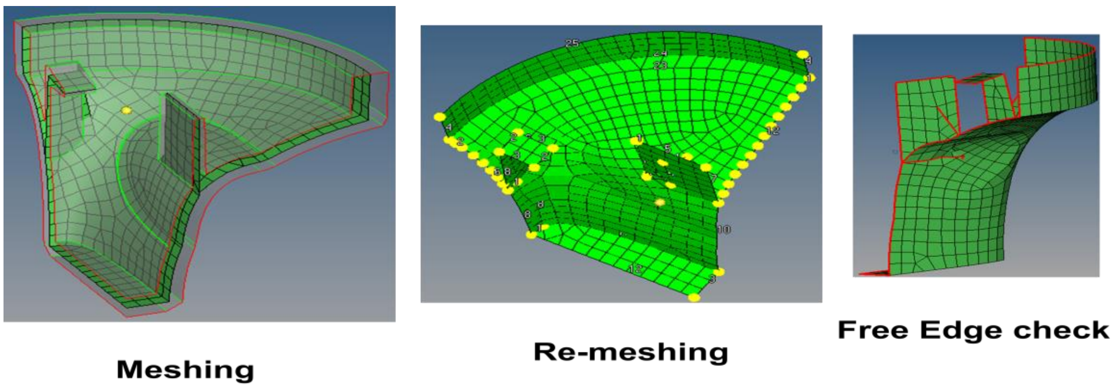


Figure 4: Meshed Portion.

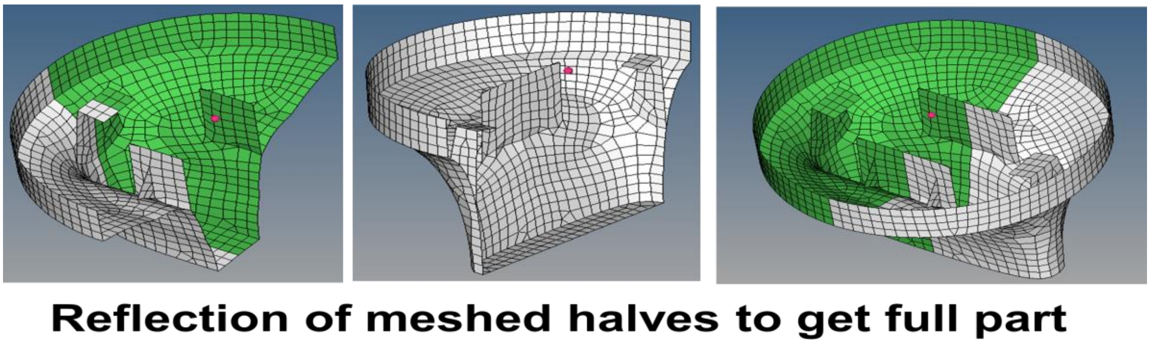


Figure 5: Reflection of Meshed Halves.

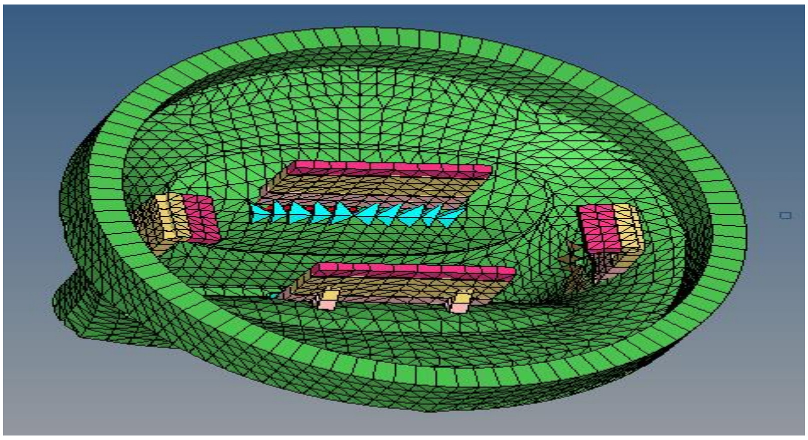


Figure 6: The Complete Meshed Part.

MATERIAL DETAILS

Material: ABS

Acrylonitrile-Butadiene-Styrene (ABS) offers superior processibility, appearance, low creep, excellent dimensional stability, and high impact strength.ABS is produced by a combination of three monomers: acrylonitrile, butadiene, and styrene. Each of the monomers imparts different properties.

Morphologically, ABS is an amorphous material.

Grade: **ABS MP220N**

- Melt density (gm/cc): 0.96
- Solid density (gm/cc): 1.03
- Mold Shrinkage (mm/mm): 0.51%
- Melt temperature: 195 - 235 °C
- Mold temperature: 40 – 80 °C
- Total Heat Content: 72 cal/gm
- Thermal Conductivity:6.0x 10^{-4} cal/sec.cm

- Injection Pressure: 700 - 1400 kg/cm^2
- Max shear stress: 0.3Mpa
- Max shear rate: 50000 1/s
- Elastic Modulus: 2240 MPa
- Melt flow rate: 25 g/10 min with 10kg load @220 °C

Target Limits

- Pressure: 75 MPa
- Temperature drop: -20 °C
- Shear rate: 50,000 1/s

Hot gate system is used for this simulation.

GATE LOCATION ANALYSIS

This will suggest a suitable gating position on the geometry, where the flow resistance will be low to inject the material.

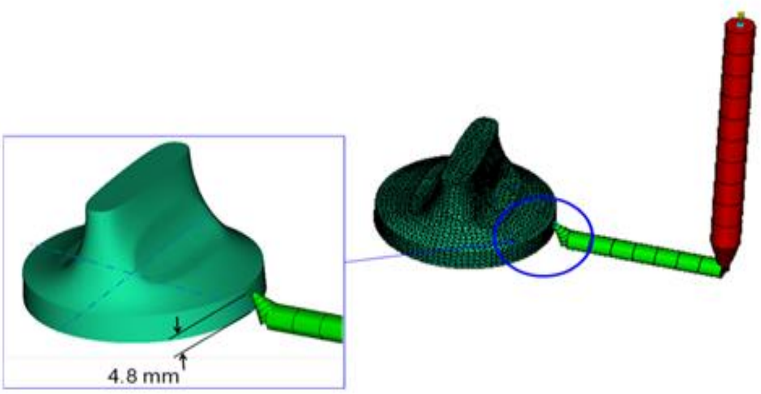


Figure 7: Gating Suitability.

Optimization of Gate Diameter and Location

The gate diameter is optimized with the help of the pressure limit, temperature drop target limit from the molding window and also from the theoretically calculated values of the shear rate. The shear rate is calculated from the formulae given below,

$$\dot{\gamma} = \frac{32\,Q}{\pi D^{3}}$$

where,

Q = flow rate

D = diameter of the gate.

From the calculations, the preferred gate dia is **1.1 mm** for the submarine gate. If we increase the gate dia the shear rate will further decrease, but the temp drop will be increased.

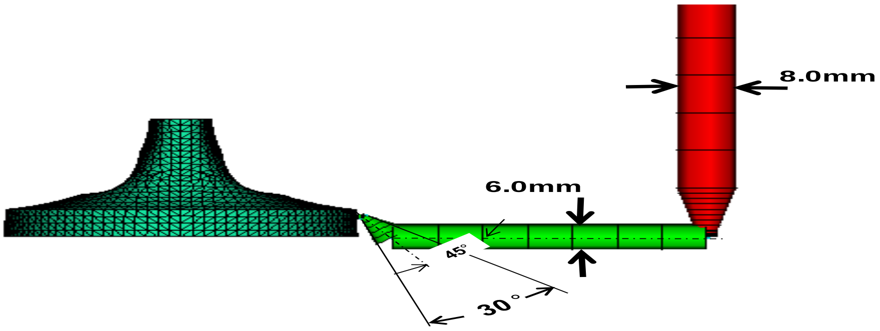


Figure 8: Hot Gate System with Position.

Gate Size Optimization

Table 2: Gate Size Optimization

Ø_gate/ mm	n gates	1					
	fill_time						
	1.7	1.92	2.14	2.36	2.58	2.8	
0.50	5.18E+05	4.58E+05	4.11E+05	3.73E+05	3.41E+05	3.14E+05	
0.60	3.00E+05	2.65E+05	2.38E+05	2.16E+05	1.97E+05	1.82E+05	
0.70	1.89E+05	1.67E+05	1.50E+05	1.36E+05	1.24E+05	1.15E+05	bad
0.80	1.26E+05	1.12E+05	1.00E+05	9.10E+04	8.33E+04	7.67E+04	
0.90	8.88E+04	7.86E+04	7.05E+04	6.39E+04	5.85E+04	5.39E+04	
1.00	6.47E+04	5.73E+04	5.14E+04	4.66E+04	4.26E+04	3.93E+04	
1.10	4.86E+04	4.30E+04	3.86E+04	3.50E+04	3.20E+04	2.95E+04	good
1.20	3.74E+04	3.32E+04	2.97E+04	2.70E+04	2.47E+04	2.27E+04	

The highlighted row result is considered as the optimum one, and the simulation plots for those parameters with hot gate system is given below.

Pressure at Injection Location

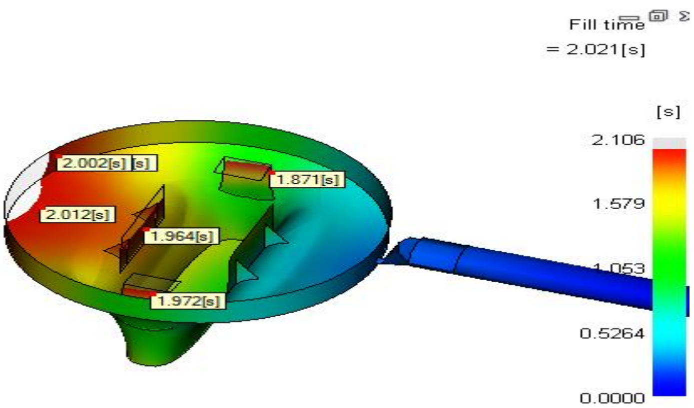
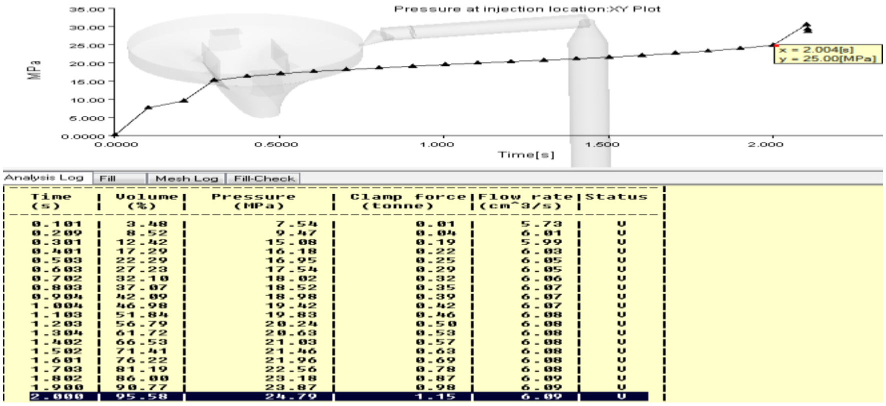


Figure 9: Pressure at Injection Location.



Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s)	Status
0.101	3.48	7.54	0.01	5.73	V
0.209	8.52	9.47	0.04	6.01	V
0.301	12.42	15.08	0.19	5.99	V
0.401	17.29	16.18	0.22	6.03	V
0.503	22.29	16.95	0.25	6.05	V
0.603	27.23	17.54	0.29	6.05	V
0.702	32.10	18.02	0.32	6.06	V
0.803	37.07	18.52	0.35	6.07	V
0.904	42.09	18.98	0.39	6.07	V
1.004	46.98	19.42	0.42	6.07	V
1.103	51.84	19.83	0.46	6.08	V
1.203	56.79	20.24	0.50	6.08	V
1.304	61.72	20.63	0.53	6.08	V
1.402	66.53	21.03	0.57	6.08	V
1.502	71.41	21.46	0.63	6.08	V
1.601	76.22	21.96	0.69	6.08	V
1.703	81.19	22.56	0.78	6.08	V
1.802	86.00	23.18	0.87	6.09	V
1.900	90.77	23.87	0.98	6.09	V
2.000	95.58	24.79	1.15	6.09	V

Figure 10: Graph Plotting Pressure at Injection Location.

The pressure required for injecting the material into the mold is 25MPa.

Shear Rate Plot

This plot shows the shear rate (rate of plastic sliding over the next layer) of the material while the polymer enters the mold through the gate. If it goes beyond the target limit the material will degrade.

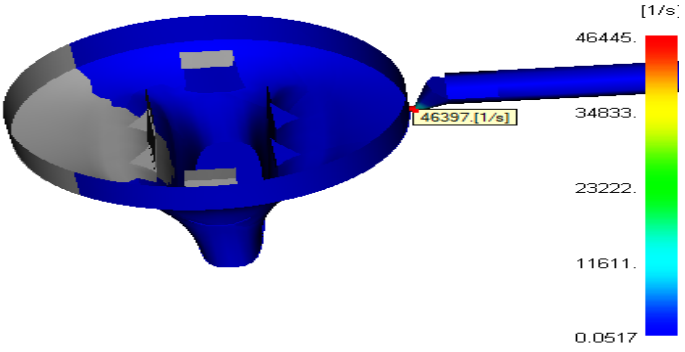


Figure 11: Shear Rate.

Temperature at Flow Front

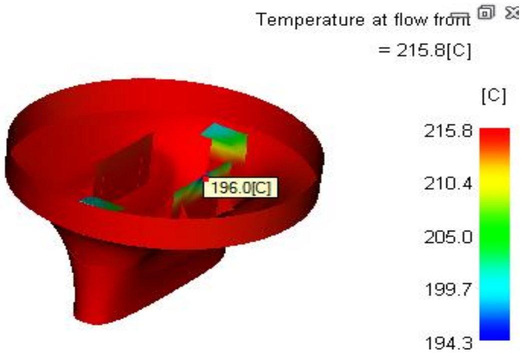


Figure 12: Temperature at Flow Front.

The Flow front temperature during the filling process is shown in this plot which is within the target limit of - 20 °C

Pressure @ V/P Switch Over

This plot shows the pressure distribution through the flow path inside the mold at the switchover point from velocity to pressure control. It is not advisable to fill the mold 100% during the injection phase itself, because there may be a chance of over packing or the orientation as the molecule changes.

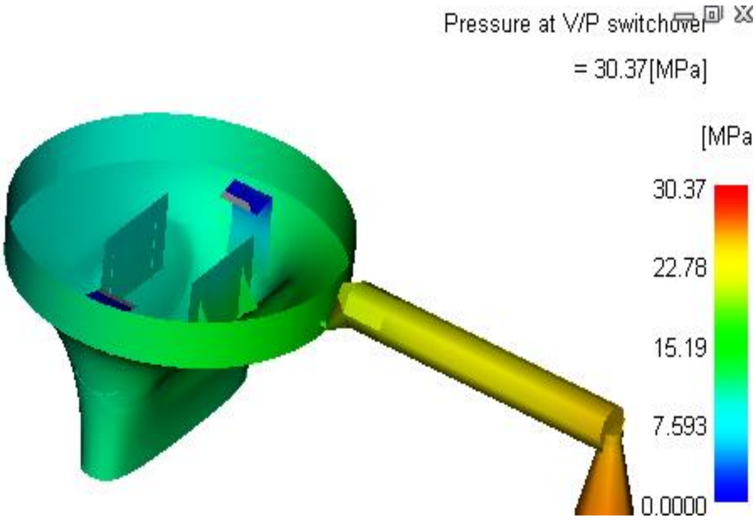


Figure 13: Pressure @ v/p Switch Over.

Air Trap Location

Air traps occur when converging flow fronts surround and trap a bubble of air. Proper venting must be provided to avoid the defects due to air trap formation.

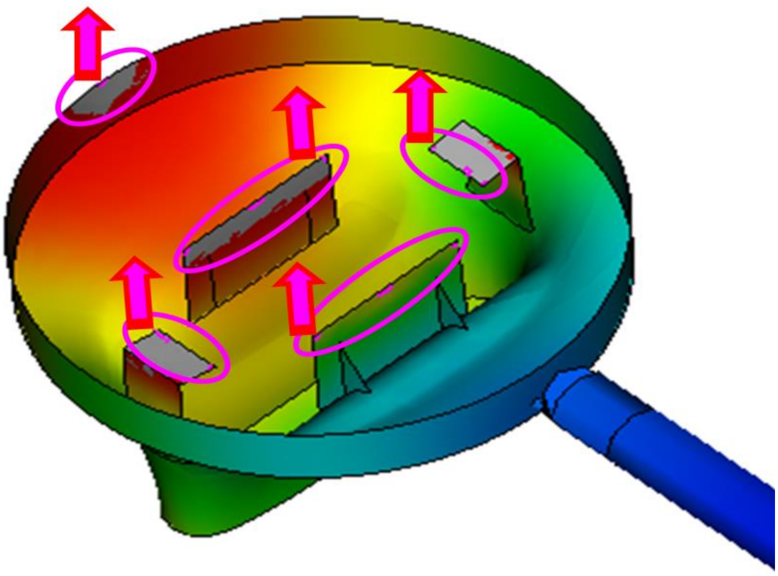


Figure 14: Air Trap Location.

Volumetric Shrinkage

Shrinkage is a function of thickness, so always consider the effects that changes in thickness might have on warpage.

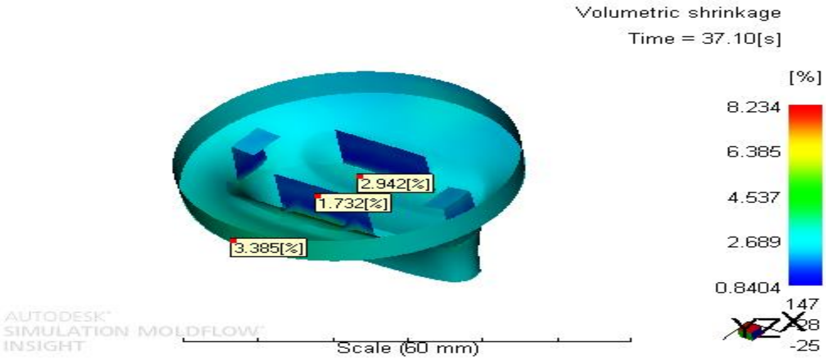


Figure 15: Shrinkage.

Warpage

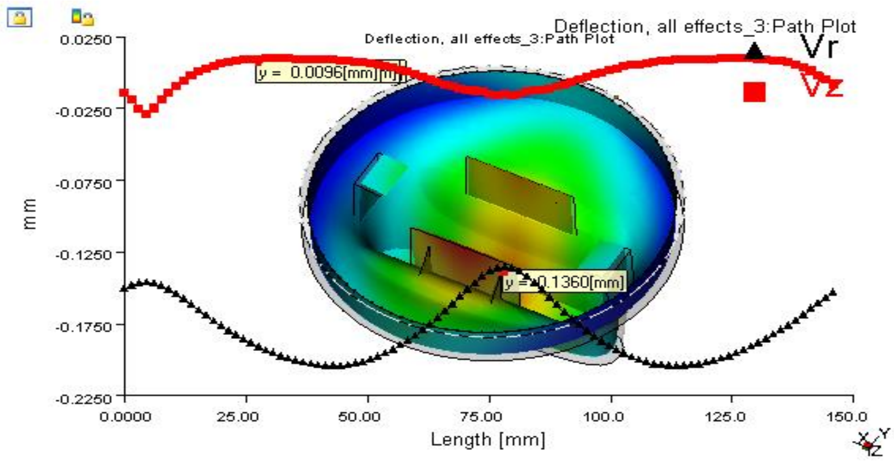


Figure 16: Warpage

ESTIMATION OF CYCLE TIME

Cycle time = Fill time + Packing time + solidifying time + Mold opening, Ejection and closing time

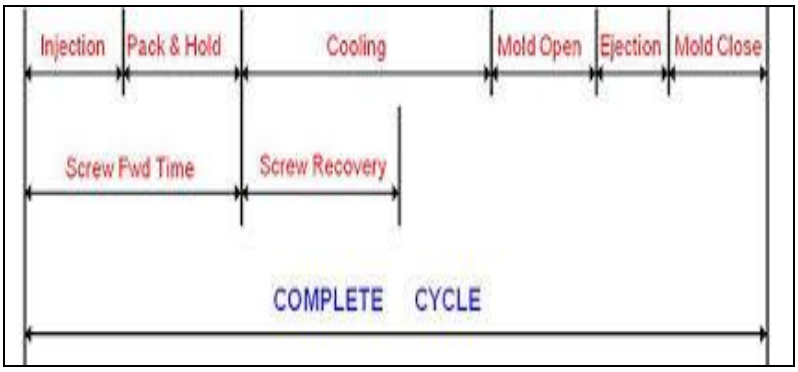


Figure 17: Complete Cycle

Fill time

- Injection of material into the impression is equal to fill time.
- Fill time = 2.0sec (from mold flow)

- Packing time = 15.0 SEC
- Solidifying time = 18.0 sec
- Mould opening and closing time
- Approximately 5 sec.

CYCLE TIME = 2.0+15.0+18.0+5.0 = 40 sec

SIMULATION RESULTS

Table 3: Simulation Results

Simulation	Result
Material	ABS MP220 N
Injection time	2.0 sec
Mold temperature	215 °C
Melt Temperature	60 °C
Gate diameter	1.1 mm
Mold material	Tool steel P-20
Temperature drop at flow front	20 °C
Clamp Force	5.6 Tonnes
Pressure @v/p switchover	30.4 MPa
Shear rate	46445 1/s

CONCLUSIONS

- The part shows no hesitation to fill with gate diameter of 1.1mm and injection time of 2.1 s. Submarine gate selected for auto degrading in the mould with small witness mark and no projection or pip at gate.
- Proper venting must be provided in tool to avoid the defects such as burn mark, hesitation due to air trap formation.
- Cycle time**: 40 sec**

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